The Acquisition of Joint Programs: The Implications of Interdependencies

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The movement toward transformation and joint capabilities has created new challenges for program acquisition efforts. The research reported in this article examines the implications of joint capabilities on acquisition. In short, the research investigates how program interdependency, size, age, and developmental status influence the occurrence of programmatic breaches. The findings provide empirical evidence that metrics that are capable of measuring interdependency may prove fruitful as an early indicator of joint program acquisition shortfalls.

With weapon system investments expecting to top the $1 trillion mark for the 2003-2009 time period, unprecedented attention has been devoted to clarifying the determinants of program risk, failure, and success [1]. The difficulties associated with averting and predicting adverse program outcomes such as cost and schedule breaches is not only a source of external criticism [2] and internal attention [3], it has illuminated deficiencies in current practices of program management and oversight. To date, there is significant debate regarding the factors that influence the outcomes of Department of Defense (DoD) programs. As such, the root causes of cost growth, schedule delay, and poor performance have received increased attention over the years [4].

Adding fuel to the fire is the fact that DoD acquisition investments are increasingly concentrated in very large, complex *system of systems* and net-centric designs. Despite the ongoing acquisition difficulties (that stymied past) and current efforts, DoD is in the process of radical transformation to a world predicated on joint capabilities – thereby leaving managers scrambling to identify new processes and metrics to support the new joint acquisition paradigm. In the case of the transformation, acquisition goals are shifting from individualized single system solutions to universal solutions that service joint needs. As such, many changes are under way in the acquisition arena and the search is on for a clearer understanding of how various acquisition strategies either support or impede joint efforts.

It comes as little surprise that the acquisition of joint programs is considerably more difficult than those of single-service programs. The reasons for the increased difficulties are often attributed to diverse requirements and complex management structures. As a consequence, joint programs are often criticized for taking longer and costing more than single service acquisitions. Some argue that joint (or interdependent) programs are not unlike single system initiatives – not differing in any important respects. The difference is simply one of scale; long-standing programmatic activities remain salient. Others argue that interdependent programs differ from single system efforts in fundamental ways that demand unique programmatic strategies and methods.

The research described in this article seeks to shed light on the controversy by asking if *jointness* matters. The following discussion focuses on the results of a cross comparison of single and joint acquisition efforts. The research stems from the perceived need to improve the ability to accurately gauge the cost and schedule demands of joint efforts. The overall goal of the research was to empirically test whether joint acquisition efforts encountered greater difficulties than their single system counterparts – and if so, to shed light on the nature of those difficulties. As discussed further on, the research examined 84 Acquisition Category (ACAT) 1[1] weapon system programs that were under development during the 1997-2005 time period. This research hopes to contribute to an understanding of the underlying causal factors that challenge joint efforts for the purpose of finding strategies that can enhance the success rate of joint capabilities.

Table 1: *Variables and Definitions*

Variable	Definition
Program Status	Indicates whether the program is single or joint.
Program Size	Total program cost in constant dollars.
Program Stage	Current stage of the program in terms of development or production.
Program Age	Years since entering Milestone B[3] status.
Schedule Breach	A program receives a schedule breach when the schedule exceeds most recent APB[4] schedule estimate by six months.
RDT&E Breach	A program receives an RDT&E breach when the research, development, testing, and evaluation costs exceed 15 percent.
Other Breach	Summation of the number of program acquisition unit cost, average procurement unit cost, procurement, and Nunn-McCurdy Breaches.

Understanding *Jointness*: A Closer Look at Interdependence

The desire for joint capabilities mandates, by definition, the establishment of interdependencies. Interdependent activities are not new to DoD or to government in general. However, what is new is the scale to which interdependent actions are currently applied. For most organizations, interdependence is pursued as a means to leverage the collective assets of various organizations located at different points along the value chain. In the DoD arena, joint capabilities are actualized by establishing interoperable systems. And the efforts promise to offer significant benefits. For example, in the command and control process, military operations benefit when commanders can seek, synthesize, and disseminate several types of information that derive from different organizations. Experts in a variety of areas must collaborate to effectively create and execute battle plans. These experts may come from different disciplines (or specialties), different branches of the military, or even different countries. In short, joint capabilities are achieved through the interoperable systems that allow interdependent activities to occur.

Interdependency is typically defined

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as the degree to which the performance of one activity (or system) relies on an external activity (or system) for its accomplishment [5]. Interdependencies can often take several forms. Most frequently they will be in the form of technical interfaces but they can also be financial, materiel, or task-based. And they do incur a cost that is not present in non-interdependent efforts [6]. Transaction costs are the costs that arise from the establishment and maintenance of interdependencies [7]. They are the costs associated with conducting the transactions that allow the transfer of data, capital, or labor, and they are often manifested in the form of labor costs and tend to be distributed across all labor categories. The search for joint solutions, the costs of bargaining and negotiation, and the ongoing costs of monitoring and enforcing the agreements of the interdependent activities are all manifestations of transaction costs.

To date, the central question that received scholarly and practitioner attention was not *what will a given interdependency cost?* but rather *under what situations will (or should) organizations incur the costs of interdependencies?* The failure to be concerned about the true nature of the costs was largely due to the presupposition that organizations would not engage in interdependent actions if the cost outweighed the benefits. This presupposition works well when organizations have the benefit of choice. However, in the government sector, and in the DoD's case specifically, legislative requirements eliminate the opportunity to choose the most efficient path. Government agencies are often asked to incur the costs of interdependent activities in return for the benefits of synergy. Little is actually known about how to estimate the cost, schedule, and risk of interdependent activities. The lack of metrics and techniques for gauging interdependencies (and their associated transaction costs) may prove especially problematic in light of the scale of the interdependent activities that are currently under way. Whether long-standing, single-system driven methods for estimating acquisition cost, schedule or risk remain salient predictors is a topic of much debate. Thus, the study of whether interdependent actions demand unique methods and metrics is an important, albeit over-looked, consideration.

The Research Study

To test whether single-system efforts differed from their joint counterparts, we examined 84 active DoD weapon system programs in terms of the number and type of programmatic breaches they encountered. In short, we examined the programs on the occurrence of schedule breach and RDT&E cost breach. We restricted the analysis to the study of programmatic breaches[2] because they provided significant indicators of the program's fitness. As such, they provide good insight into the extent to which schedule and cost problems occur. Table 1 provides a definition of the variables used in the analyses reported below. The data were collected in the autumn of 2006 and all information was derived from quarterly Selected Acquisition Reports (SAR) and Defense Acquisition Executive Summary reports. The following section provides the findings of the investigation.

The first research question sought to identify whether joint systems differed from their single system counterparts. In short, it attempts to address the controversy that the two (joint versus single efforts) are similar in all but scale. To test this assertion, the 84 programs were

Figure 1: *Single System vs. Joint System*

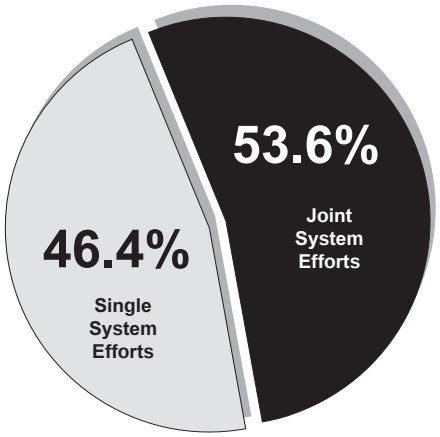


Figure 2: *Average Number of Breaches (1997-2005)*

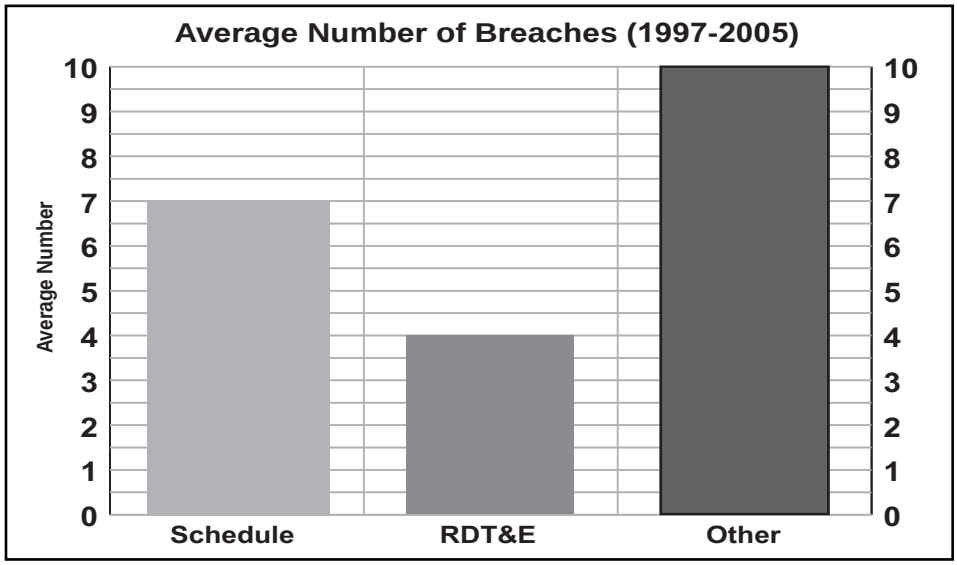
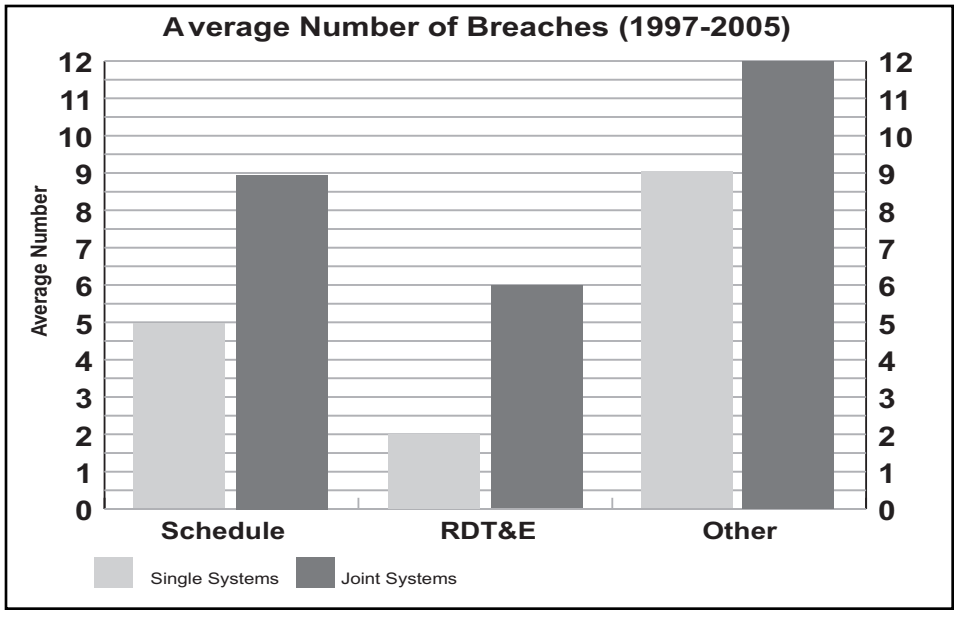


Figure 3: *Average Number of Breaches by Status (1997-2005)*



Variable	Mean Single Status	Mean Joint Status	Between Group Sum of Squares	Df	F Ratio	Sig
Schedule Breaches	4.58	8.6	341.75	1	5.19	.025
RDT&E Breaches	1.65	5.95	388.23	1	12.14	.001
Other Breaches	7.85	11.59	293.22	1	1.68	.198

A One-Way Analysis of Variance is a statistical procedure that tests the equality of three or more means at one time by using variances. The analysis of variance procedure compares the ratio of between group variance to within group variance. If the variance caused by the interaction between the groups is much larger when compared to the variance that appears within each group, then it is believed that the means are significantly different. Each sum of squares has corresponding degrees of freedom (Df) associated with it. The total Df is one less than the number of observations, N-1. The **F ratio** is the test statistic used to decide whether the sample means are within sampling variability of each other. That is, it tests the hypothesis H_0: $\mu_1 ... \mu_g$, thus it is equivalent to regression procedures in that it tests whether the model as a whole has statistically significant predictive capability.

Table 2: *ANOVA With Program Status a Factor Variable*

divided into two groups based on whether their SAR mission definition indicated any partnership relationships with any other MDAP programs. Thus, *Single System Efforts* did not indicate any partnership of jointness, whereas *Joint Systems Efforts* explicitly indicated a partnership/joint status. (A full list of the 84 programs can be found at <www.stsc.hill.af.mil/crosstalk/2007/06.stc.html>.) Of the 84 active programs, 46.4 percent (39 programs) were classified as single system efforts and 53.6 percent (45 programs) were identified as joint systems (see Figure 1, page 21).

In terms of the overall characteristics of the sample, the average age was six years. Approximately 54 percent were in the development stage and approximately 46 percent had already entered production and the average total program cost was $18 billion (in 2005 dollars). As noted in Figure 2 (see page 21), schedule breaches tended to be the most problematic for the programs under study (recall that *other* is the summation of a number of breaches, none of which in isolation rose to the level of RDT&E of schedule breaches). The average program experienced roughly seven schedule breaches and four RDT&E cost breaches over the 1997-2005 time frame. The average program also experienced roughly 10 *other* breaches (such as procurement, program acquisition unit cost and average procurement unit cost – see Table 1).

Furthering this examination, Figure 3 (see page 21) identifies the average number of breaches by the joint/single status. Single system efforts averaged roughly five schedule breaches, whereas the joint programs encountered approximately nine schedule breaches. The differences were statistically significant at conventional levels. Single systems also differed from their joint counterparts on RDT&E cost breaches. Single system programs had, on average, two RDT&E breaches, whereas joint efforts averaged six RDT&E breaches. With respect to the *other* breaches, single systems averaged nine breaches and joint systems averaged 12.

To test whether the differences were statistically significant, analysis of variance (ANOVA)[5] tests were conducted. As demonstrated in Table 2, the two groups (single versus joint) were statistically significant at conventional levels for both the schedule and the RDT&E breaches ($p < .025$ and $< .001$ respectively). While the two groups differed in terms of the number of *other* breaches, the differences failed to achieve statistical significance. Given that the status (single versus joint) of the program proved to be a significant indicator of schedule and RDT&E breach, a series of subsequent tests were conducted to test whether the program's status would continue to prove to be a good indicator of breach when controlling for the effects of age, size, and stage of development[6].

Data were obtained from the 2005 SAR on each of the program's age, size, and stage of development and three multivariate regression[7] tests were conducted. The first regression model tested for the influence of status on schedule breaches controlling for size, age, and stage. As demonstrated in Table 3, controlling for size, age, and stage, the program's status (joint/single) continued to be an indicator, albeit weak as noted by the $p < .059$, of schedule breach. The effects of status (holding constant size, age, and stage) on RDT&E cost breaches also proved robust. For these 84 cases, size, age, and stage did not prove to be significant indi-

Table 3: *Regression Results for the Effects of Size, Age, Stage, and Status on Programmatic Breach (1997-2005)*

Variable	Unstandardized Coefficients		Beta	t	sig
	b	Std. Error			
Dependent Variable: Schedule Breaches					
(Constant)	3.372	1.901		1.774	.080
Size	-8.17E-006	.000	-.037	-.323	.748
Maturity	.209	.218	.117	.959	.341
Stage	.390	2.027	.024	.192	.848
Status	3.628	1.896	.220	1.914	.059
Dependent Variable: RDTE Breaches					
(Constant)	.848	1.311		.647	.520
Size	-2.24E-005	.000	-.140	-1.282	.204
Maturity	.027	.151	.020	.178	.859
Stage	1.667	1.398	.138	1.192	.237
Status	4.539	1.307	.377	3.472	.001
Dependent Variable: Other Breaches					
(Constant)	3.757	3.051		1.231	.222
Size	-2.87E-005	.000	-.081	-.706	.482
Maturity	.448	.350	.154	1.279	.205
Stage	3.110	3.254	.116	.956	.342
Status	4.637	3.043	.173	1.524	.132

A linear regression line has an equation of the form $Y = a + bX$, where ***X*** is the explanatory variable and ***Y*** is the dependent variable. The slope of the line is ***b***, and the constant (***a***) is the intercept (the value of ***y*** when ***x*** = 0). In the regression procedure, the unstandardized coefficient ***b*** is the slope of the independent variable. The standard errors of the regression coefficients are used for hypothesis testing and constructing confidence intervals. The Standardized coefficients (Beta) are what the regression coefficients would be if the model were fitted to standardized data. The **t** test is a test of significance. It tests the hypothesis that a population regression coefficient β is 0, that is, H_0: β = 0. It is the ratio of the sample regression coefficient ***b*** to its standard error. The significance is a function of the **t** value and provides an indication of the probability that the coefficient is due to random chance.

cators of the occurrence of either schedule or RDT&E breach. And none of the variables (size, age, stage, and status) provided predictive insight into the occurrence of other breaches.

Due to the finding that program status continued to provide insight into schedule breaches regardless of the size, age, or stage of development, the programs were examined in light of the average number of months of schedule delays that were experienced. For the programs that encountered a schedule slippage, the average slippage was 57 months. The average cost of the slippage was calculated by first dividing the total expenditures to date by the number of months the program received funding. The cost of slippage was then calculated for each program by multiplying the programs' average monthly expenditure by the number of months slipped. For those programs that encountered slippage, the average cost of slippage was $1,818 million.

Implications for Acquisition

The results of the research provide convincing evidence to suggest that, when considering program breach as an indicator of program fitness, joint programs do in fact differ from their single system counterparts. Joint systems encountered substantially more breaches than did single system efforts. And, the effects of status as a reliable indicator of breach, held true regardless of the program's size, age, or stage of development. These results suggest that joint programs, whether large or small, in development or production, and irrespective of age, are statistically more likely to encounter programmatic breaches than their single system counterparts.

The findings pose several salient issues for acquisition. First, the finding that joint programs differ from single systems and are more susceptible to schedule and cost breach is noteworthy. Jointness matters. Program managers involved in the acquisition of joint initiatives should heed these findings as a call to pay particular attention to attendant program risk factors as a means of mitigating potential problems. Unfortunately, the research cannot offer guidance on what forms of risk to monitor; it did not capture whether the typical single system risk factors continue to apply in a joint setting.

Furthermore, the research did not flesh out why joint efforts encounter more breaches. In other words, are there some unique characteristics of joint efforts that put them at higher risk? Or, might it be that the original estimation techniques were not well suited for joint efforts? In other words, is it the process of joint acquisition or is it the failure to accurately predict cost and schedule at the onset? This subtlety is an important distinction that warrants further investigation.

Second, little is known about the downstream cascading effects of interdependencies. Isolating the risk factors for the spill-over ramifications that one program may unintentionally impose against another downstream may be vitally important in a world of joint capabilities. Spill-over effects could potentially explain why large programs breach despite the intense management oversight applied to them; it may be due to the spill-over effects of upstream, interdependent programs.

If joint capabilities is, in fact, a paradigm worth pursuing, then these findings indicate that further research on programmatic interdependencies is not just warranted, but imperative.

Third, the findings suggest that size, age, and stage offer little insight into the potential to breach. As such, size, age, and stage are not only *not* good early indicators, but they do not seem to offer any real immunity to breach. This finding tends to question the merits of the traditional approaches to classifying major defense acquisition programs for in-depth scrutiny solely on the basis of size or cost alone.

The results appear fairly clear – more applied research is definitely needed. Testing to see whether breaches are more related to one form of interdependency than another may prove helpful to acquisition managers that must navigate the choppy waters of joint efforts. It is quite plausible that different forms of interdependencies exist and that they will not all manifest the same influences. Additional research is also needed on how different forms of interdependency may interrelate to place a program at either higher or lower risk. Moreover, given the findings, further research may substantiate that interdependencies exhibit unique cost characteristics (see the discussion on page 21 on transaction costs) that may require distinct methods and metrics for estimating (and monitoring) program cost, schedule, and risk.

Finally, the findings indicate that the acquisition process is not impervious to the transformational activities underway in the DoD. As program structures change in important ways (i.e. from single to joint), it comes as little surprise that the management metrics, measures, and methods employed to undergird program acquisition would require modification. Additional insight into the specific nature of interdependencies and the management levers that act to tame the problems that interdependencies spawn, is clearly warranted.

While these findings provide important insights into the acquisition of joint programs, the findings should be interpreted with caution. The limitations of the study (for example, the one-point in time snapshot view, the limited manner of classifying interdependence or *jointness*, and the failure to include other important factors that may prove significant) cannot be overlooked. Nonetheless, the results provide reason to pursue the study of *interdependence* as a potential indicator of programmatic outcomes.

If *joint capabilities* is, in fact, a paradigm worth pursuing, then these findings indicate that further research on programmatic interdependencies is not just warranted, but imperative.◆

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Notes

1. Programs that are estimated to require an eventual total expenditure for research, development, testing and evaluation (RDT&E) of more than $365 million in fiscal year (FY) 2000 constant dollars or, for procurement, of more than $2.190 billion in FY 2000 constant dollars are classified as ACAT 1 programs.
2. The Acquisition Program baseline (APB) monitors program development metrics. Performance outside the predicted thresholds results in programmatic breaches. These breaches are viewed as unfavorable outcomes for program development.
3. Milestone B marks the beginning of the System Development and Demonstration stage of program acquisition. It is the first stage that requires a formal acquisition strategy that will be employed to track and monitor program progress.
4. The APB requires every program manager to document program goals prior to program initiation. Program managers identify set goals and a series of objective values that serve to provide thresholds for monitoring progress.
5. ANOVA is a statistical method that tests whether the averages (means) of two groups are statistically different. It does this by calculating a mean for the entire sample and then comparing it against the mean of each group. As such, it tests whether the individual group's mean differs from the entire population.
6. In modeling relationships between two variables, statisticians are often asked to test whether the relationship may actually be due to the actions of a third variable. For example, perhaps it is not the joint nature that leads to breach, but rather it is the size of the program. By including size, age, and stage in the multiple regression model, we can isolate the effects of jointness irrespective of the program's age, stage, and size. In this way we are *controlling* for any effects that size, age, or stage may impose on breaches.
7. Regression techniques test for the extent to which one variable is a direct function of another variable. In short, it examines how much of the dependent variable can be explained or predicted by knowing the value of the independent variable. It is capable of testing both the strength and the direction of the relationship between two variables. It is also capable of testing the effects of multiple variables on one dependent variable – in this case, it is referred to as *Multiple Regression*. For further insight into these techniques, see: Lind, Douglas, William Marchal, and Robert Mason. "Statistical Techniques in Business and Economics." 11th ed. New York: Irwin/McGraw-Hill, 2002 or <www2.chass.ncsu.edu/garson/pa765/index.htm>.

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